RATION ENERGY DENSITY AND TIME ON FEED EFFECTS ON BEEF LONGISSIMUS PALATABILITY

by

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Chapter I

Introduction

Palatability factors, especially tenderness, play an important role in consumer acceptance of beef. Demands are for high quality, tender, juicy and flavorful cuts of beef. Therefore, much research has been done on factors affecting these traits.

Studies of antemortem factors influencing tenderness, juiciness and flavor have primarily revolved around animal age, carcass maturity or marbling. However, numerous studies have shown marbling to have a low, positive correlation with tenderness. Furthermore, for beef cattle less than 30 months of age, and most fed cattle in the United States are in this age category, only small differences in tenderness have been noted within and between marbling groups.

Recent work on palatability and marbling has focused attention to populations from similar feeding backgrounds. Marbling increases as time on feed (Zinn *et al*. 1970a) and as ration energy density increases (Guenther *et al*. 1962, 1965), and may be considered as a reflection of the growth (finishing) process. Increasing time on feed or ration energy density may play an important role in palatability independent of the influence marbling has on eating quality.

Some studies indicate that palatability increases as time on feed increases (Kropf et al., 1975; Harrison et al., 1978; Leander et al., 1978) and as ration energy density increases (Cover et al., 1957; Smith et al., 1977). Feed costs are a major expense of beef production. Reduction of these costs could be achieved by shorter feeding periods or by using rations with more roughage. Yet, consideration needs to be given to the effects this would have on palatability and other acceptance factors of beef.

The purpose of our study was to study the effects of ration energy density and time on feed on the palatability of beef. Carcass traits that play an important economic role in beef marketing were also studied.

Chapter II

REVIEW OF LITERATURE

Time on feed effects on carcass composition

Carcass composition is often measured by either chemical analysis of soft tissue or by carcass characteristics related to retail yield. Carcass measurements of fatness are positively related and retail yield is negatively related with total fat content (or percentage) of the carcass (Callow, 1948; Preston *et al*., 1968). Therefore both methods will be considered when discussing affects of time on fed on carcass composition.

Days on feed endpoints

Days on feed effects on carcass composition are not as thoroughly studied as weight or age effects on composition. Also, such factors as sex, breed, biological type of cattle, and ration energy level may alter time on feed effects on composition.

Zinn *et al*. (1970a) fed 100 steers and 100 heifers 0 to 270 days before slaughter (30 day increments). Cold carcass weight increased numerically at all end points, but the increase was nonsignificant from 60 to 90 days and from 180 to 210 days. Dressing percent significantly increased between endpoints of 30 to 60, 90 to 120 and 210 to 240 days on feed.

Proximate analysis of the semimembranosus, longissimus and triceps brachii muscles of 50 steers and 50 heifers slaughtered every 30 days from 0 to 120 days on feed showed percentage crude protein, ether extract and crude ash increased as length of feeding time increased but moisture decreased (Zinn et al., 1963a).

Bull et al. (1930) fed Hereford steers (168 kg starting weight) a shelled corn or corn silage ration for up to 266 days. As length of feeding increased, dressing percent and kilograms of trimmable fat increased. Slaughter weights were 168, 323, 373 and 386 kg for control, 140, 200 and 266 day groups, respectively. Percentage of trimmable fat increased considerably from 0 to 140 days of feeding, but, increased only slightly from 140 to 200 days on feed. No significant increase in fat percentage occured from 200 to 266 days. Lean percentage decreased slightly from 0 to 140 days of feeding and varied little from 140 days to 266 days. Zinn et al. (1963b) also reported no significant changes in percentage of carcass fat trim from 150 to 270 days on feed.

Dinius and Cross (1978) fed a concentrate ration to Hereford steers after feeding alfalfa for 105 days. From a starting weight of 424 kg, fat deposition increased from 0 to 9 weeks on feed as indicated by increased fat thickness, percentage kidney, heart and pelvic fat and increased yield grade number.

Moody et al. (1970) fed 338 kg steers a high silage ration for 28, 56, 84 and 112 days and noted increased dressing percent, slaughter weights (338 to

437 kg) and decreased percentage retail yield of carcass weight as feeding time increased. Loin eye area increased from 28 to 56 days, but changes were non-significant after 56 days. Kidney, heart and pelvic fat increased from 56 to 84 days.

Shinn et al. (1976) reported increases from 0 to 112 days on feed in dressing percent, (50.7 to 57.1), fat thickness (.18 to .86 cm) and decreases in retail yield (72.7 to 69.5 percent) for cattle fed 0, 56 or 112 days after pasture. A larger decrease in retail yield occured from 56 to 112 days (72.4 to 69.5) compared with 0 to 56 days (72.7 to 72.4). Slaughter weights were 284, 375 and 454 kg for the 0, 56 and 112 days groups.

Judge et al. (1978) fed cattle from three starting weights and slaughtered them at 454 kg. Longer feeding periods increased percent kidney fat ($p < .02$), even though carcass weights were similar.

Age endpoints

Results from studies involving age usually parallel those of days fed. Moulton et al. (1922a) used three groups (full feed, maximum gain without fat deposition and .45 kg gain per day) of Hereford-Shorthorn steers fed from 3 to 48 months of age. Dressing percentage decreased up to $8\frac{1}{2}$ months then increased. Percentage carcass plus offal fat (empty weight basis) increased up to 40 months with no real increase from 40 to 48 months. In the full fed group percentage lean increased

up to $8\frac{1}{2}$ months and then decreased to 48 months.

Using the same cattle Moulton et al. (1922b) found a decrease in percentage water of carcass soft tissue from 73% at birth to 39% at 48 months, while carcass fat increased from 4% at birth to 45% at 48 months. Nitrogen increased from 2.9% to 3.3% at 3 months, but decreased to 2% for full fed cattle at 48 months. Percent ash increased slightly from birth to 48 months in slower gaining groups, but decreased from 3 months to $5\frac{1}{2}$ months for the faster gaining group. Kilograms of fat, water, nitrogen and ash increased as age increased from birth to 48 months. Water and nitrogen amounts increased up to about 20 months then increased only slightly to 48 months.

Henrickson et al. (1962) reported decreases in percentage of lean meat in carcasses (due to fatness) as the age of the animal advanced from 6 to 90 months. Total pounds of lean steadily increased to 42 months of age, but increased only slightly after 42 months.

Weight endpoints

Preston (1971) states that weight produces a strong influence on carcass composition. He concluded that "in studies where differences have occurred in final weight due to the plane of nutrition, sex, breed, etc., it can be predicted ahead of time that differences will occur in carcass composition due to this difference in final weight at which composition is evaluated. For this reason, a large volume of the literature is hard

to interpret since the influence of the factors being studied is confounded with differences in weight at which composition was evaluated."

Haecker (1920) studied carcass composition changes with increasing slaughter weight for steers slaughtered at 45.4 kg increments from 45.4 kg to 680.4 kg. As slaughter weight increased the total weight of fat, protein and ash increased. Fat percentage increased from 4.0 to 37.59 with the greatest increase occuring from 362.9 to 408.2 kg (5.56%). Protein percentage declined from 19.89 to 15.72 with only a small decrease between 45.4 to 362.9 kg. (1.09%) and percentage of water decreased (71.84 to 43.38%). Percent ash decreased between 45.4 kg and 454 kg but changed little after 454 kg. At 362.9 kg slaughter weight, percentage fat was about equal to percentage protein.

Jesse et al. (1976) used weight endpoints of 227, 241, 454 and 545 kg and noted that carcass fat increased from 17.25 to 38.11%, carcass protein decreased from 18.39 to 13.4%, carcass water decreased from 60.47 to 46.53% and carcass ash decreased from 3.89 to 1.96%. The greatest increase in fat occurred after 341 kg, and empty body fat and protein percentage were equal at this weight.

Sex effects on composition

Hedrick (1968) reviewed differences in composition due to sex. Dressing percent is believed to be higher for heifers than steers on a constant weight comparison.

Bulls have less finish than steers or heifers, regardless of age, weight, or days on feed, and steers have less finish than heifers when compared at the same endpoints. Helser et al. (1930) observed a faster rate of fat deposition in heifers than in steers as length of feeding period increased.

Biological type effects on composition

Much of the earlier work measured differences between dairy and beef type cattle. Comparisons are complexed by the type of endpoint used to evaluate the composition. Judge et al. (1965) compared carcass composition of Angus, dairy and dual purpose cattle. Angus carcasses were fatter and had a lower percentage of edible portion than either dairy or dual purpose cattle at a constant age. Younger Angus carcasses had similar composition to the older dairy or dual purpose cattle. Hedrick (1968) stated that a major compositional difference between dairy and beef breeds is in distribution of fat, since dairy breeds have a higher proportion of internal fat.

Kidwell and McCormick (1956) considered differences in mature weights of Holstein and Herefords. At equal initial weights, Holsteins (greater mature size) had more muscle and less fat when full fed for a similar time. In a review by Klosterman (1972) he generalized that for different types fed to the same weight, larger types are likely to be leaner, but within a breed faster gaining cattle are fatter when fed the same time.

Ration energy level

Ration energy density could alter time on feed effects on composition by changing the rate of weight change. On an age endpoint comparison, ration energy level affects carcass composition and retail yield (Moulton et al., 1922a, 1922b). Fat percentage increased at a greater rate for cattle on full-feed than for either cattle on maintenance or cattle on a ration producing .45 kg per day gain. Percentage nitrogen decreased from 3.3% at three months to 2% at 48 months in full-fed cattle, but remained constant for the other two groups. Lean percentage (retail yield) of the full-fed group increased to $8\frac{1}{2}$ months then decreased. But, the percent lean of carcasses of steers fed for maintenance or for 0.45 kg gain/day was similar up to 45 months of age.

Jesse et al. (1976) fed steers four rations varying in corn and corn silage ratios and slaughtered them at weight endpoints of 227, 341, 454 and 545 kg. Percentage of carcass fat increased and carcass protein, water and ash decreased as weight increased. However, ration did not interact with slaughter weight effects on carcass composition.

In general: carcass composition is probably more strongly related to weight than to time on feed; as days fed increases, total amounts of lean (protein), fat and ash increase and percent lean (protein) decreases and percent fat increases, with fat increasing at a much faster rate after slaughter weights from 319 to 369 kg.

Ration energy level effects on carcass composition

Increasing ration energy level generally increases carcass fatness. However, results in the literature are complicated by different approaches to experimental design and analysis of data such as comparing at a constant time on feed, age, weight, fat depth, longissimus fat, or quality grade. Differences in ration energy level achieved by varying the amount of roughage and concentrate (ration energy density) or by restricting feed intake give similar results.

Time on feed or age endpoints

At a constant time on feed, as ration energy level increases, percentage of carcass fat increases and percentages of carcass protein and water decreases, (Bull et al., 1930; Garrett, 1974: Guenther et al., 1962; 1965; Lofgreen, 1968) and amount of fat trim and muscle increases but percentage retail yield decreases (Ferrell et al., 1978; Foster and Miller, 1933; Guenther et al., 1962, 1965; Matthews and Bennett, 1962; Prior et al., 1977; and Trowbridge et al., 1918; Waters, 1908). Using constant age as an endpoint, similiar results were observed for constant carcass fat, protein and water percentages (Burton et al., 1969; Moulton et al., 1922b; Stuedemann et al., 1968) and for retail yield (Moulton et al., 1922a) when feeding rations differing in energy.

Slaughter or carcass weight endpoints

When comparisons are made on a constant time fed or a constant age basis, increasing ration energy level also increases daily gain resulting in different slaughter weights. Therefore, relative differences in carcass composition could be due to differences in slaughter weight. In a review, Berg and Butterfield (1968) stated: "it is not possible to conclude whether plane of nutrition has an effect on the relative growth of muscle and bone or if it is merely involved with slowing down or speeding up of the whole process in a normal allometric manner."

Carcass composition expressed either as percentages of fat, protein, and water, or percent retail yield, fat thickness, kidney and pelvic fat percentage, and loin eye area was significantly affected by ration energy level when slaughter weight endpoints were used (Anderson, 1975; Bondari et al., 1977; Bull et al., 1930; Dilley et al., 1959; Garrigus et al., 1969; Henrickson et al., 1965; Judge et al., 1969; Judge et al., 1978; Lofgreen, 1968; Oltjen et al., 1971; Wanderstock and Miller, 1948) or when a constant carcass weight was calculated (Prior et al., 1977; Smith et al., 1977).

Comparisons may be slightly different for constant carcass weight and constant slaughter weight. Differences in ration energy densities result in differences in gut fill and dressing percent, resulting in different

carcass weights for similiar slaughter weights (Guenther *et al*., 1965).

Ferrell *et al*. (1978) showed trends ($P < .10$) for ration energy density effects on carcass composition at a constant carcass weight. Guenther *et al*. (1965) reported non-significant effects for ration energy density on percentages of carcass fat and retail yields, but noted that the higher energy cattle had more carcass fat and lower retail yields. Others report no difference in carcass composition due to ration energy level at a constant slaughter weight (Burton *et al*., 1969; Jesse *et al*., 1976; Miller *et al*., 1966; Minish *et al*., 1966; Preston, 1971; Riley, 1969; Stuedeman, *et al*., 1968) or at an adjusted carcass weight (Prior *et al*., 1978). Reid *et al*. (1968) felt variations in empty body weight due to nutrition account for variations in muscle and fat.

Anderson (1975) fed four levels (55, 70, 85 and 100 percent *ad. libitium*) to seven slaughter weight endpoints ranging from 180 to 540 kg (60 kg increments). Percentage of lean, bone and fat of the four energy levels were not different at slaughter weights of 180 to 300 kg; but, fat percentage and dressing percentage decreased and bone and lean percentage increased with decreased feed intake at heavier slaughter weights of 360 and 540 kg.

Similar results were noted by Waldman *et al*., (1971) with Holstein steers fed *ad. libitium* or for gains of 60 to 70 percent of *ad. libitium*. At slaughter weights

of 341, 455 and 590 kg, greater amounts of carcass fat and higher ratios of fat to muscle were reported for the _ad. libitum_ steers. Muscle weights were greater for the slower gaining steers at 455 and 590 kg. Jesse _et al_. (1976) found no differences due to ration energy density on carcass fat, protein or water percentages at slaughter weights of 341, 455 and 545 kg for Hereford steers. Others also report nonsignificant differences in carcass composition due to ration energy density at slaughter weights of 350 kg (Riley, 1969), 325 and 335 kg (Guenther _et al_., 1962) and to an adjusted carcass weight of 311.5 kg (Prior _et al_., (1978).

Ferrell and Crouse (1978) reported no differences in composition at 560 kg slaughter weight, but stated that their ration energy densities of 2.77 verses 3.17 MCal ME/kg were not great enough to result in detectable differences. Preston (1971) felt that ration energy level within practical dietary possibilities would not affect gross chemical composition of the carcass, but that composition may be affected by low planes of nutrition.

Oltjen (1971) fed Hereford steers to 452 kg on either an all pelleted forage ration or an all concentrate ration and noted greater fat cover for steers fed the concentrate ration. Utley _et al_. (1975) fed an all forage versus an all concentrate ration and reported lower yield grades for the forage fed cattle group. Dilley _et al_. (1959) noted carcasses of 463 kg steers fed 60%

of full feed had the least separable fat and greatest separable lean compared with 80 and 100% full feed groups. Garrigus _et_ _al_. (1969) found that steers fed hay in the early part of the feeding period had less fat trim and a higher percentage of edible portion than steers fed corn silage for the same period. Some compositional differences have also been noted for moderate and high energy rations at similar slaughter weights (Henrickson _et_ _al_. 1965).

Marchello and Hale (1976) stated that cattle on reduced planes of nutrition early in the feeding period and then placed on full feed had carcasses with altered composition for a period of time. However, these animals have carcasses similar in composition to those full fed once slaughter weight is reached, suggesting a prolonged growth phase.

Longissimus fat percentage or marbling endpoints

Some comparisons between ration energy densities have been made at a constant _longissimus_ fat percentage or marbling endpoint. Smith _et_ _al_. (1977) adjusted to 4% _longissimus_ fat and reported steers fed a moderate energy ration were leaner than steers fed a higher or lower energy ration. Lofgreen (1968) calculated differences to constant grade and found carcass fat and protein percentages were similar for cattle fed high roughage or high concentrate.

Fat depth endpoints

Marchello *et al*. (1977) fed calves three levels of concentrate to a constant twelfth rib fat depth as determined ultrasonically. Concentrate level did not influence ($P > .05$) fat thickness, rib eye area, kidney fat amounts, extractable fat and retail yield. Cole *et al*. (1966) used three fat thickness endpoints determined ultrasonically and reported ration had no apparent affect on muscular and skeletal development. Young and Kauffman (1978) fed Hereford steers to 1.0 cm fat thickness (determined ultrasonically) and reported that grain feed steers had greater fat thickness and higher yield grades than steers fed corn silage or haylage-corn silage rations.

Biological type and ration energy density effects on composition

Prior *et al*. (1977) found that level of nutrition may affect fat level differently for different sizes of cattle. Steers were classified as "small type" or "large type" according to their breeding and fed one of three ration energy densities by varying the ratio of corn silage to corn plus supplement. Carcasses from the large type steers had similar carcass traits for the different rations when adjusted to a carcass weight of 403.5 kg.

When carcasses from the small type steers were adjusted to 319.3 kg, significant differences due to ration energy density were observed for fat thickness,

kidney and pelvic fat percentage, and yield grades. Carcasses from the small type fed the low energy ration (43:57 corn silage to corn plus supplement ratio) were trimmer than carcasses from steers fed the medium (25:75) and high energy (11:89) rations; but, carcasses from steers fed medium and high energy rations were similar in fatness.

This is contradicted by Ferrell _et al_. (1978), Smith _et al_. (1977) and Ferrell and Crouse (1978) who reported no interactions for cattle type and ration energy density when considering carcass characteristics on a constant carcass weight.

In general, increasing ration energy level increased carcass fat on both a constant time on fed or constant slaughter weight basis. However, significant differences may depend on magnitude of the differences in ration energy and the final slaughter weight at which comparisons were made. Heavier (fatter) cattle generally show greater compositional differences.

Time on feed effects on marbling

In general, as time on feed increases, marbling increases(Bull et al., 1930; Costello et al., 1975; Dinius et al., 1978; Guenther et al., 1962; Harrison et al., 1978; Judge et al., 1978; Leander et al., 1978; Moody et al., 1970; Shinn et al., 1976; Zinn et al., 1970a).

Bull et al. (1930) reported marbling scores increased up to 200 days on feed; but not from 200 to 266 days. Moody et al. (1970) found that marbling scores of steers fed from 338 kg increased from 28 to 84 days on feed; but marbling scores were similar for 84 and 112 days on feed.

Zinn et al. (1970a) concluded that intramuscular fat deposition proceeds in a stepwise manner. They slaughtered steers and heifers from 30 to 270 days on feed at 30 day increments and noted marbling scores significantly increased from 0 to 30 days, 90 to 120 days, 180 to 210 days and 210 to 240 days.

Judge et al. (1978) found that calves started on feed at a lighter weight, and consequently were on feed longer, had higher marbling scores than calves on a shorter feeding period fed to the same slaughter weight of 454 kg.

Ration energy level effects on marbling

Ration energy level effects on marbling are not in total agreement in the literature, but lowering energy intake appears to decrease marbling when comparisons are made at a constant time fed or slaughter weight endpoints.

Time on feed endpoints

Guenther et al. (1965) fed Hereford steers medium or high energy rations (57.4 and 15.0% cotton seed hulls) and reported higher marbling scores for the high energy ration on a time constant endpoint.

Matthews and Bennett (1962) fed 272 to 318 kg steers for slow or fast gain for 28, 63 and 77 days and indicated that ration energy level had significant affects on marbling. Guenther et al. (1962) fed medium and high energy rations to Hereford steers. When calves on the high energy ration gained 90.7 kg gain, they had one degree of marbling higher than calves fed medium energy ration for the same time. After 181 kg gain there were two degrees of marbling difference between the ration groups.

Slaughter or carcass weight endpoints

Miller et al. (1966) fed Holstein steers to 454 kg slaughter weight on either 11:1, 3:1 or 1:1 corn: ground alfalfa . Marbling scores increased with increased ration energy. Henrickson et al. (1965) also reported

increased marbling scores for high versus medium energy rations for carcasses from Hereford steers slaughtered at 399 kg, but noted that the range of marbling scores was small. Danner _et al_. (1977) found carcasses from cattle fed to 312 kg on concentrate had higher marbling scores than calves fed corn silage and concentrate.

Animal weight,type or relative growth stage may influence ration energy level effects on marbling. Comparing carcasses from Holstein steers fed _ad libitium_ or at 60 to 70% _ad libitium_, Waldman _et al_. (1971) reported that total extractable lipid in the _longissimus_ and _semimembraosus_ muscles was not influenced by nutritional regime until 455 kg slaughter weight. The _ad. libitum_ group had more extractable lipids at slaughter weights of 455 and 590 kg.

At constant slaughter weights, increased marbling and carcass quality grade result from all concentrate compared with all roughage diets (Utely _et al_., 1975; Oltjen _et al_., 1971). However, Lofgreen (1968) found differences in marbling scores were small when yearlings were fed to a constant slaughter weight on a high roughage or a high concentrate ration. Riley _et al_. (1969) felt that final carcass grade was not directly associated with ration energy level at a constant slaughter weight.

Dilley _et al_. (1959) reported carcasses of steers fed 60% of full feed had more marbling than carcasses from steers fed 80 or 100% full feed when slaughtered at 462 kg.

Johnson *et al*. (1969) felt that restricted growth due to lower ration energy in the early part of the feeding period did not affect intramuscular fat deposition during that period, but that it would delay the tendency for fat deposition in muscle when a higher energy ration was subsequently fed. This seemingly contradicts results of Ewing *et al*. (1961) who reported less rib eye intramuscular fat for steers full fed corn throughout the feeding period than for steers fed rations for maintenance or .68 kg gain per day in the early feeding period.

Biological type and ration energy level

Prior *et al*. (1977), using two types of cattle and three energy densities, adjusted means to a constant carcass weight and reported similar marbling values for carcasses of large type steers, on different rations. Carcasses of small type steers had less marbling for the low ration energy group as compared with the medium and high energy group.

Factors affecting meat palatability

Palatability factors of meat include tenderness, juiciness and flavor. Tenderness is considered by the consumer to be the most important factor (Bratzler, 1971) and has been extensively studied. However, the factors involved in tenderness and the methods for achieving uniform tenderness are not completely understood.

Tenderness

Meat is primarily composed of protein, water and lipid, plus small fractions of carbohydrates, minerals and other organic compounds. Of the major components, water and lipid would contribute very little to meat toughness; therefore, the protein portion is the major factor affecting tenderness.

Locker (1960) proposed that tenderness could be resolved into two component parts: "background toughness" or connective tissue toughness and "actomyosin toughness" or myofibrilliar toughness. This division helped explain conflicts of earlier research indicating connective tissue amount was strongly related to tenderness while other data had low or no relationship between connective tissue and tenderness.

Myofibrilliar tenderness is difficult to measure independent of the connective tissue effects. However, toughness due to "cold shortening" has been associated with myofibrilliar tenderness (Marsh, 1972). Cold

shortening in muscle reduces meat tenderness by increasing actomysin cross linkages. Though connective tissue could also play a role in toughness due to cold shortening by increasing the "crimp" of endomysial connective tissue (Rowe, 1974).

Dutson (1974) stated in a review that total collagen was assumed to be primarily associated with tenderness differences between muscles. Tenderness associated with animal age was not strongly related to total collagen but was related to the percentage of soluble collagen, or collagen cross-linking.

Nutrition of beef cattle could affect connective tissue and myofibrilliar tenderness. It was pointed out earlier in this review that increasing the ration energy level or time on feed increases carcass fatness. With the supposition that "cold shortening" is slowed or avoided by insulatory effects of fat cover, nutrition could indirectly affect myofibrilliar tenderness. Dilution of the amount of connective tissue during fattening (Batterman et al., 1952) or changes in the structure of collagen are also possible ways that ration energy or time on feed effects tenderness.

Increasing days on feed may be more important than marbling effects on tenderness as Crouse et al. (1978) reported a higher association for days on feed than marbling to taste panel acceptability. Furthermore, correlations between marbling and taste panel acceptability

were reduced when days on feed was held constant.

Juiciness

Juiciness is comprised of the combined effects of initial fluid release upon chewing and sustained juiciness resulting from the stimulating effect of fat on salivary flow (Weir, 1960). Cooking procedure or degree of doneness influences juiciness and is primarily associated with initial juiciness; whereas sustained juiciness is more closely related to the fat content of the meat (Pearson, 1966). Variations in juiciness can be accounted for by the differences in fat, moisture and water holding capacity of the meat (Berry, 1972).

Juiciness may be related to tenderness. Tender meat will allow quicker release of the fluids upon chewing and gives a greater sensation of juiciness; however, in tough meat the juiciness is greatest and more uniform if the release of fluid and fat is slow (Weir, 1960). Increasing days on feed or ration energy level would increase fat content and subsequently increase juiciness. However, as lipids increase in muscle, water content decreases which would tend to decrease juiciness.

Flavor

Flavor sensations result from a combination of factors including odor, taste, texture, temperature and muscle pH. The chemical components of meat responsible for meat flavor have not been completely identified.

However, meaty flavors are associated with the lean or water soluble factions and flavor differences between species are related to the fat characteristics (Smith and Carpenter, 1974).

Flavor measurements are highly subjective and highly variable between individuals.

Differences in intensity of flavor can result from variation in animal age, muscle differences, muscle pH, cooking procedure, and the processing method (Lawrie, 1966).

Time on feed effects on palatability

Leander *et al*. (1978) used three groups of cattle fed either 180 days on fescue grass, 180 days grass plus 56 days on grain or 180 days of grass plus 112 days grain. Taste panel scores were higher and shear values were significantly lower for the 112 day grain group compared with the grass fed group. Cattle fed 56 days had intermediate tenderness scores indicating a gradual increase in tenderness with increasing days fed. Others have shown similar increases in tenderness for cattle fed different lengths after grass (Kropf *et al*., 1975; Harrison *et al*., 1978; Shinn *et al*., 1976). However, Smith *et al*., (1977) reported that taste panel tenderness differences of grass fed cattle and grain fed cattle were small and disappeared after 49 days on a 20% or 60% forage ration. Moody *et al*. (1970) fed steers for 28, 56, 84 and 112 days before slaughter and noted no trend in taste panel tenderness, juiciness and Warner Bratzler shear values of *longissimus* steaks for time on feed.

Increases in tenderness due to days fed may depend on ration energy level before the start of experiment; but complete ration history is mostly unreported for many projects. Dinius and Cross (1978) fed Hereford steers ground alfalfa 105 days before feeding a high concentrate (85%) ration for 0, 3, 6 or 9 weeks. No

significant differences due to feeding time were found for taste panel traits (tenderness, juiciness, flavor and connective tissue amount) or shear force. Small but consistant increases in taste panel connective tissue, tenderness and juiciness scores and a decrease in shear force were reported between the 0 to 3 week feeding periods.

In the Dinius and Cross (1978) study, steers weighed 424 kg at 0 time. Matthews and Bennett (1962) used Hereford and Shorthorn steers with beginning weights as heavy as 318 kg and felt they were too heavy to find palatability differences. They fed either a high or low energy ration for 28, 63, and 77 days but did not report previous ration history.

Judge et al. (1978) fed three weights of Hereford steers (201, 227, or 286 kg) three levels of ration energy (corn and corn silage) to a 454 kg slaughter weight. Steers that were lighter in weight and on feed longer had higher taste panel juiciness scores. Those on feed for an intermediate time had the highest taste panel flavor scores.

Age endpoints

Studies of age effects on palatability are often designed similar to studies of time on feed relationships to palatability. Jacobson and Fenton (1956) reported that increasing age of fed Holstein heifers from 33, 48,

64, and 80 weeks resulted in decreased taste panel tenderness and juiciness. Tenderness decreased with increasing age from 3 to 67 months (Hiner and Hankins, 1950). However, for steers under 30 months of age at slaughter, Alsmeyer et al. (1959) reported that age at slaughter accounted for only 5.6 percent of the variation in taste panel tenderness. Carroll et al. (1976) reported no significant differences in tenderness within marbling groups due to carcass maturity for cattle up to 30 months of age.

Time on feed effects may be complexed by animal age, especially in very long trials. Zinn et al. (1970b) fed 100 heifers and 100 steers and slaughtered them at 30 day intervals from 30 to 270 days on feed. Decreases in average shear values for three muscles were reported for the 120 to 180 day groups, but increases in shear values were noted after 180 days on feed. They stated that this increase was due to a greater influence of age (430 days old) after 180 days on feed. Similar trends were observed by Simone et al. (1958). But, Crouse et al. (1978) reported residual correlations indicating taste panel traits were more highly associated with days fed than with carcass maturity. Their steers were slightly older than those reported by Zinn et al. (1970b).

Muscle and time on feed

The initial decrease, then increase in shear values

with increasing days fed (Zinn et al., 1970b) was not consistant for all muscles studied. The *triceps brachii* was their most tender muscle (lowest shear values) and its shear values displayed no consistant pattern with days fed. Shear values of *longissimus* and *semimembranosus* muscles decreased early then increased later in the feeding period. *Longissimus* samples were most tender at 150, 180 and 210 days on feed and *semimembranosus* samples were most tender from 60 through 210 days on feed.

Tender cuts appear to have smaller or no differences due to days on feed. Jacobson and Fenton (1956) reported decreasing tenderness with increasing age up to 80 weeks for the *longissimus* and *semimembranosus* muscles but the *psoas major* was not affected by increasing age. Juiciness decreased in all muscles with increasing age.

Sire or biological type and time on feed

The role of genetics in days on feed effects on palatability has been studied by using different sires and by comparing different cattle types. Epley et al. (1968) fed calves from 12 different sires for 139, 167, 195, 223 and 251 days after weaning. Taste panel flavor intensity and desirability was not related to days fed, but taste panel tenderness and overall desirability showed a sire by days on feed interaction ($P < .01$). No differences were noted for days fed for some sires,

in others maximum tenderness was at 167 days. Still others displayed a decrease in tenderness only after feeding 251 days. Warner-Bratzler shear values however, did not have a significant sire by days fed interaction and were higher at 251 days than at 139 and 167 days on feed. Their consumer panels detected no significant tenderness or overall desirability differences for time on feed.

Smith et al. (1977) fed two types of cattle on one of five feeding regimes of grass, different ration energy densities and feeding periods. They found no differences due to cattle type or type by ration interactions; therefore, the two types were analyzed together for days fed. Taste panel traits (tenderness and overall acceptability) were not affected by days fed.

Ration energy level and time on feed

Ration energy density may interact with time on feed effects on palatability. Crouse et al. (1978) stated that length of time on feed was positively associated with taste panel acceptability, tenderness, juiciness and flavor within a feeding regime. However, feeding regimes that required more days on feed to reach slaughter weight (slower gaining, lower energy rations) were negatively associated with taste panel acceptability.

Graham et al. (1959) fed steers one of four rations (maintenance, full feed hay, concentrate plus full feed hay, and full feed of a fattening ration) to 5, 10, 16

or 23 months of age and showed a significant ration by age interaction for juiciness. Taste panel tenderness was not affected by age, but Warner-Bratzler shear values decreased with increasing age.

Many other workers have reported no significant interaction for days fed (or age) and ration energy (Jacobson and Fenton, 1956; Judge _et al_., 1978; Matthews and Bennett, 1962; Moody _et al_., 1970; Prior _et al_., 1977).

Ration energy level effects on palatability

Numerous studies have shown no significant effects of ration energy level on palatability (Bull et al., 1930; Callow, 1961; Christensen et al., 1978; Cole et al., 1966; Costello et al., 1975; Davies, 1977; Dezinleski et al., 1976; Henrickson et al., 1965; Matthews and Bennett, 1962; Paul, 1962; Wanderstock and Miller, 1948; Wellington et al., 1954). However, significant ration energy level effects on palatability have been reported by Cover et al. (1957), Dube et al. (1971), Foster and Miller, (1933), Jacobson and Fenton (1956), Smith et al. (1977), and Oltjen et al. (1971).

Ration energy level effects on palatability of meat may depend on the deviation above or below maintenance energy levels, the muscle studied and the biological type or breed of cattle.

Significant ration energy effects on palatability seem to occur with the lower ration energies close to maintenance levels. Dube et al. (1971) found longissimus and biceps femoris steaks from steers fed corn silage were more tender (Warner-Bratzler shear, and taste panel tenderness, residue and number of chews) than steaks from steers fed hay when slaughtered at constant weights.

These differences in taste panel scores and shear values may have been partially attributed to younger ages of the silage fed cattle. However, Graham et al.

(1957) reported that Warner-Bratzler shear values decreased and taste panel tenderness and juiciness scores increased as ration energy(maintenance, full feed hay, concentrate plus full feed hay, and full feed of a fattening ration) increased for steers slaughtered at a constant age. Differences in palatability have also been reported between differing ration energy densities well above maintenance. Cover _et al_. (1957) reported taste panel juiciness and tenderness scores increased and shear values decreased for broiled _biceps femoris_ muscles from steers fed 70% concentrate - 30% hay compared with those from steers fed 35% concentrate - 65% hay for 156 days. However, no significant differences occurred for taste panel tenderness and juiciness of broiled or braised _longissimus_ steaks. Smith _et al_. (1977) used rations of 20% forage (3.11 Mcal ME/kg), 60% forage (2.84 Mcal ME/kg) or grass, and observed similar values for palatability traits of steaks. When means were adjusted to a constant time on feed, ration energy significantly influenced taste panel traits giving slightly lower acceptability scores for steaks from grass fed cattle. No differences for ration energy level were observed by adjusting to constant carcass weight or 4% fat in the _longissimus_. Prior _et al_. (1977) fed large and small type steers three rations varying in the ratio of corn silage to corn plus supplement (low 43:57; medium 25:75; high 11:89). _Longissimus_ steaks from the medium

energy group had higher taste panel tenderness and acceptability scores than the low energy group. The high energy group steaks were intermediate but not significantly different in palatability than both the low and medium energy groups. No significant differences for ration energy level were noted in Warner-Bratzler shear and taste panel flavor or juiciness scores.

Muscle and ration energy level

Ration energy level effects on palatability also depend upon the muscle studied. Cover *et al*. (1957) reported increases in tenderness with increasing ration energy for bottom round steaks (*biceps femoris*)when broiled at 200 C. However, tenderness of rib steaks (*longissimus*) was not affected by ration energy level when prepared by either broiling or braising above boiling water. This seemingly contradicts results of Jacobson and Fenton (1956) who found increased taste panel tenderness for the *longissimus* with ration energy but no increase for the *psoas major*, *semimembrancsus* or adductor from Holstein heifers fed different TDN levels. Shear force values were variable and inconclusive for all muscles studied by Jacobson and Fenton (1956).

Biological type and ration energy level

Breed or biological type does not seem to interact with ration energy level. Cover *et al*. (1957) compared Hereford and Hereford-Brahama crosses on two ration

energy levels and reported no significant breed by ration interactions. Smith et al. (1977) also found no significant type by ration interaction when using large and small type cattle. However, Prior et al. (1977) did find significant differences in ration energy on taste panel tenderness and acceptability for small type cattle (Angus X Hereford) but no differences in taste panel traits for the large type (Charolais and Chianina) on the same rations. Significance level of the type by ration energy level was not reported. Opposite effects on shear values were observed in the cattle types.

Cold shortening effects on tenderness

Sarcomere length is related to tenderness (Herring et al., 1965) and decreases in sarcomere length are associated with "cold shortening". Tenderness decreases as sarcomeres shorten with exposure to cold (Marsh and Leet, 1966). However, taste panel muscle fiber tenderness does not relate well with sarcomere lengths greater than 1.8 um (Bouton et al., 1973).

Chilling rates

Cold shortening is related to the chilling of muscle which depends on the chilling temperatures, carcass mass, amount of overlying tissue (fat or other muscle) (Marsh et al., 1972) and fat content of the muscle (Cross et al., 1972).

Delaying cold temperature application postmortem reduces the extent of cold shortening (Marsh and Thompson, 1958), and little or no cold shortening occurs if rigor cross linkages are formed (Marsh and Leet, 1966). However, in prerigor muscle (above pH 6.0), cold shortening occurs when muscle temperatures are below about 8 C. (Chrystall, 1976). Davey et al. (1971) stated that a chilling rate exceeding 1.4 C per hour in the deep tissue of a beef side during the first six hours of chilling produced cold shortening.

Muscle mass and fat effects on cold shortening

Parrish et al. (1973) held beef carcasses at either 2 or 16 C. Due to the insulatory effect of muscle mass and fat cover, cold shortening effects on tenderness were minimal, even at 2 C. Wenham et al. (1973) suggested that larger, mature ram carcasses chill slower than smaller lamb carcasses. They also suggested that thinner ewe carcasses chilled at a higher temperature were equal in tenderness to fatter lamb carcasses chilled at a lower temperature. Increased fat added insulation and slowed chilling rate.

Smith et al. (1976) worked with lambs from three finish levels (fat thickness) of thick, intermediate or thin. Carcass weight differences were noted for the different finish groups (thick finish was heaviest and thin finish was lightest), but the weight differences

were credited to the differences in carcass fat rather than muscle mass. Carcasses of the thick and intermediate groups chilled more slowly than carcasses of the thin group, indicating fatter (or heavier) carcasses chill slower than thinner (or lighter) carcasses. Longissimus sarcomere length was longer for the thick and intermediate groups compared with the thin group. Taste panel traits measuring myofibrilliar tenderness were highest for the thick finished group.

Effects of fat cover on chilling rate and tenderness in beef carcasses are reported by Meyer et al. (1978). Fat cover over the short loin was removed from the left side of the carcass of 10 Angus steers (521 to 634 kg live weight). Hourly temperatures of the longissimus were significantly lower for the defatted sides. Less desirable taste panel traits (tenderness, juiciness, flavor and overall desirability) and higher shear values ($P < .05$) were observed for steaks from the defatted loins.

Merkel and Pearson (1975) suggest major differences in tenderness between fatter, higher grading and thinner, lower grading beef are due to (marbling and subcutaneous) fat effects on slowing heat loss and reducing cold shortening. Cold shortening appeared greatest in carcasses chilled at normal temperatures with less than 1.27 cm subcutaneous fat. As fat thickness decreased below 1.27 cm cold shortening became more pronounced.

Cross *et al*. (1972) reported correlations ($P < .01$) for sarcomere length and intramuscular fat in carcasses of ewes and wethers fed different ration energy densities to a constant weight, indicating marbling can effect cold shortening. Correlations for sarcomere length and muscle fat on a whole tissue basis ($r=.31$) and on a moisture free basis ($r=.37$) were reported.

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Chapter III

RATION ENERGY DENSITY AND TIME ON FEED EFFECTS ON BEEF *LONGISSIMUS* PALATABILITY

Introduction

Beef palatability plays an important role in consumer acceptance. The present quality grading system (USDA, 1976) places major emphasis on marbling in determining beef quality. However, numerous reports have found correlations between marbling and taste panel tenderness are low (Parrish, 1972), leaving the need for a better system of determining beef palatability.

Feed costs, a major expense in beef production, could be reduced by shorter feeding periods or by using rations with more roughage. However, consideration should be given to how these changes affect palatability.

Type of feed and length of finishing time may influence beef palatability (Allen *et al.*, 1977). Studies involving increasing time on feed have shown increases in taste panel tenderness (Harrison *et al.*, 1978; Kropf *et al.*, 1975; Leander *et al.*, 1978; Shinn *et al.*, 1976) and juiciness (Judge *et al.*, 1978). The increase in tenderness may occur early in the feeding period (Smith *et al.*, 1977; Zinn *et al.*, 1970b). However, Dinus and Cross (1978), Matthews and Bennett (1962) and Moody *et al.*

(1970) found no differences in taste panel tenderness, juiciness or flavor intensity, and Warner-Bratzler shear force as time on feed increased, Epley _et al_. (1968) even reported higher Warner-Bratzler shear force values for steaks from steers fed 251 days compared with those fed 139 days.

Ration energy density may also influence palatability. Improved palatability with increased ration energy density has been shown by Cover _et al_. (1957), Dube _et al_. (1971), Jacobson and Fenton (1956) and Smith _et al_. (1977). Yet others have reported no affect of ration energy density on palatability (Callow, 1961; Cole _et al_., 1966; Henrickson _et al_., 1965; Matthews and Bennett, 1962; Wanderstock and Miller, 1948).

The combination of time on feed and ration energy density effects on palatability is still unclear. Crouse _et al_.(1978) stated that longer time on feed was associated with improved taste panel acceptability, tenderness, juiciness and flavor intensity within a feeding regime. However, feeding regimes that required more days on feed to reach slaughter weight were negatively associated with taste panel acceptability.

The purpose of our study was to determine the affect of time on feed and ration energy density on beef _longissimus_ palatability.

Materials and Methods

Treatments. One-hundred-twelve Angus yearling steers of similar background were randomly assigned to each of 14 nutritional treatment combinations (eight per treatment) after a 21 day ration (corn silage) adjustment period. A control (C) group was slaughtered at the end of the adjustment period, and a submaintenance (S) group, expected to lose about .5 kg/day, was fed prairie hay for 28 days, then slaughtered. The twelve remaining groups were fed either a ration of low (L), medium (M) or high (H) energy density (table 1) and slaughtered after 56, 91, 119, 147 (M and H only) or 175(H only) days on feed. Before the start of the trial, steers were on a corn silage growing ration for approximately three months.

Cattle were withheld from feed 18 to 24 hr before slaughter at a commercial packing house. Carcass data were collected after carcasses were chilled for 24 hr. Wholesale ribs from the right side of each carcass were delivered to Kansas State University Meat Laboratory for sample removal.

Sample location. The *longissimus* muscle was removed from each rib seven days postmortem and immediately fabricated into 2.5 cm thick steaks. A histological steak was removed from the 12th rib area, and from the

TABLE 1. RATION COMPONENT PERCENTAGES AND ENERGY DENSITIES ON AS-FED BASIS.

Ingredient	Internat'l ref. no.	Energy density Low	Medium	High
Corn	4-02-913	17.9	27.1	38.6
Wheat	4-05-268	17.9	27.1	38.6
Sorghum silage	3-04-468	16.8	16.5	16.3
Prairie hay	1-07-956	42.9	24.2	0
Supplement[a]		4.6	5.0	6.4
Mcal NEp/kg		.771	.992	1.28

[a]Included soybean meal, ground limestone, dicalcium phosphate, salt, trace minerals and vitamins.

10th rib area a taste panel steak and an objective textural analysis steak were removed. All steaks were individually wrapped in freezer paper, frozen and stored at -26 C until analyzed.

Taste panel analysis. Steaks for taste panel analysis were thawed a 2 C overnight and modified oven broiled (Harrison, 1975) in a rotary oven at 177 C to an internal temperature of 66 C as determined by a glass thermometer placed in the geometric center of each steak.

Cores, 1.3 cm in diameter, were removed from each steak for taste panel evaluations. A six member panel evaluated each steak for detectable connective tissue, muscle fiber tenderness, overall tenderness, juiciness and flavor intensity using eight point scales for each factor (1 = abundant connective tissue, extremely tough, dry or bland flavor; 8 = no detectable connective tissue, extremely tender, juicy or intense flavor). Six steaks from different treatment combinations were served at each session. Samples were served in random order to each panelist at each session, and no more than two sessions were held per day. Panelists were screened, trained and tested using recommendations of AMSA (1978).

Objective textural analysis. Steaks for objective textural analysis were cooked the same way as the taste panel steaks. All objective evaluations were done with an Instron Model 1123, equipped with a 500 kg load cell and strip chart recorder.

Three 1.3 cm diameter cores were removed near the subcutaneous edge of each steak with a drill press unit. Each core was sheared twice using a Warner-Bratzler (tension) attachment. Compression measurements were made on muscle strips (1.0 x 2.5 x 8 cm) with the fibers aligned perpendicular to the travel of the 8mm compression rod. Cohesiveness compression values were determined by the ratio of the work (area under the curve) for the second penetration to the work for the first penetration, and chewiness, compression values were calculated by multiplying the force (peak height) for the first penetration by the cohesiveness value. Adhesion force measurements were applied perpendicular to the fiber orientation of samples .67 x 1.0 x 8 cm. Force deformation curves for each measurement were recorded on a strip chart recorder.

Sarcomere length. Five cores 1.3 cm in diameter were removed from the medial, central, lateral, dorsal and ventral positions of each histological steak for sarcomere length determinations. Cores were placed in a plastic bag, sealed, frozen and stored at -26 C until analyzed. After cores were thawed for one hour at room temperature, the center third from each of the five cores was removed and blended at low speed in a Waring Blendor with 40 ml of cold .25 M sucrose solution for 30 to 60 seconds. Sarcomere lengths were measured with a Wild phase contrast microscope at 750X. The total

length of 10 sarcomeres each from 25 myofibrils was measured with an eyepiece filar micrometer to estimate average sarcomere length.

Statistical analysis. Data were analyzed using analysis of variance and resultant F tests for treatment effects and general linear modeling and their resultant F tests for ration energy density, time on feed and ration by time on feed effects (Barr *et al*., 1976). Duncans mean separation techniques were used to separate individual treatment means, least significant difference values were used to separate ration and time on feed means when F tests were significant.

Results and Discussion

Production and carcass characteristics. Beginning weights were similar for both ration and time on feed groups (table 2). Ending test weights increased as ration energy density (RED) and time on feed (TOF) increased, and average daily gain increased as RED increased. Average daily gain for S group was considerably different from L, M or H ration group daily gains. The difference in average daily gain between L and M RED groups were greater than the difference in average daily gain between M and H RED groups. As TOF increased average daily gain decreased between 56 and 91 days on feed. The average daily gain increase between 119 and 147 days may be biased because there was no L ration group fed for 147 days.

Treatment combination affected all carcass yield (table 3) and quality grade (table 4) factors. Means for hot carcass weight, rib eye area, kidney, pelvic and heart fat, adjusted fat thickness, marbling score and quality grade were lowest for carcasses from the S ration group and highest for H-178 group. Yield grade number was lowest for the L-56 group and highest for H-178. All carcasses were well within the "A" maturity classification.

Ration energy density and TOF effects were significant

TABLE 2. PERFORMANCE MEANS FOR RATION ENERGY DENSITY AND TIME ON FEED GROUPS OF CATTLE.

Ration[a] density	n	Beginning weight, kg	Ending weight, kg	Average daily gain, kg/day
C	8	281.6	--	--
S	8	297.4	291.7^{e}	$-.21^{e}$
L	24	283.1	353.2^{d}	$.81^{d}$
M	32	285.1	405.1^{c}	1.18^{c}
H	40	273.8	429.6^{b}	1.35^{b}
Time on feed				
56	24	280.6	351.8^{f}	1.27^{b}
91	24	277.4	375.0^{e}	1.07^{c}
119	24	282.8	408.5^{d}	1.06^{c}
147	16	283.1	469.0^{c}	1.26^{b}
178	8	269.7	484.8^{b}	1.21^{b}

[a] C = control; S = submaintenance; L = low; M = medium; H = high ration energy density.

[b,c,d,e,f] Ration or time on feed means in a column with a different superscript letter are different ($P < .05$).

TABLE 3. USDA YIELD GRADE FACTORS FOR RATION ENERGY DENSITY AND TIME ON FEED TREATMENTS

Ration[a]	Time on feed, days: 0	28	56	91	119	147	178	Mean
Hot carcass weight, kg								
C	156.6^{j}							
S		155.9^{j}						
L			175.8^{i}	189.5^{ghi}	206.8^{efg}			190.7^{m}
M			188.1^{hi}	213.0^{ef}	241.4^{d}	269.6^{c}		288.0^{l}
H			196.2^{fgh}	223.3^{e}	252.3^{d}	292.7^{b}	296.7^{b}	252.2^{k}
Mean			186.7^{o}	208.6^{n}	233.5^{m}	281.2^{l}	296.7^{k}	
Rib eye area, cm^{2}								
C	59.4^{d}							
S		51.1^{e}						
L			62.7^{d}	58.9^{d}	61.5^{d}			61.0^{m}
M			61.5^{d}	64.4^{cd}	69.1^{bc}	69.6^{bc}		66.1^{l}
H			62.9^{d}	64.8^{cd}	72.3^{b}	72.8^{b}	74.2^{b}	69.4^{k}
Mean			62.4^{m}	62.6^{m}	67.6^{l}	71.2^{k}	74.2^{k}	
Kidney, pelvic and heart fat, percentage[p]								
C	1.5^{f}							
S		1.0^{gf}						
L			.6^{i}	1.5^{f}	1.2^{fg}			1.0
M			.7^{hi}	2.0^{e}	2.0^{e}	2.9^{c}		1.9
H			.8^{hi}	2.5^{d}	2.0^{e}	2.9^{c}	3.5^{b}	2.3
Mean			.7	2.0	1.7	2.9	3.6	
Adjusted fat thickness, cm								
C	.28^{fgh}							
S		.10^{h}						
L			.13^{gh}	.33^{fg}	.32^{fgh}			.26^{m}
M			.21^{gh}	.44^{ef}	.56^{e}	.84^{d}		.51^{l}
H			.27^{fgh}	.78^{d}	.78^{d}	1.14^{c}	1.44^{b}	.88^{k}
Mean			.20^{n}	.52^{m}	.55^{m}	.99^{l}	1.44^{k}	
Yield grade								
C	1.4^{ij}							
S		1.6^{hi}						
L			1.1^{j}	1.8^{fghi}	1.7^{ghi}			1.5^{m}
M			1.4^{ij}	1.9^{fgh}	2.0^{efg}	2.7^{cd}		2.0^{l}
H			1.4^{ij}	2.4^{de}	2.2^{ef}	3.1^{bc}	3.4^{b}	2.5^{k}
Mean			1.3^{n}	2.0^{m}	2.0^{m}	2.9^{l}	3.4^{k}	

[a] C = control; S = submaintenance; L = low, M = medium, H = high ration energy density.

[b,c,d,e,f,g,h,i,j] Treatment combination means within a factor without a common superscript letter are different ($P < .05$).

[k,l,m,n,o] Time on feed means within a row with a different superscript letter are different ($P < .05$); ration means in a column within a factor with a different superscript letter are different ($P < .05$).

[p] Interaction for time on feed by ration energy density was significant ($P < .05$).

TABLE 4. USDA QUALITY GRADE FACTORS FOR RATION ENERGY DENSITY AND TIME ON FEED TREATMENTS

Ration[a]	Time on feed, days							Mean
	0	28	56	91	119	147	178	
			Average maturity[b]					
C	A-36^{j}							
S		A-50^{efgh}						
L			A-44^{ghij}	A-47^{fghi}	A-44^{ghij}			A-45
M			A-40^{hij}	A-44^{ghij}	A-37^{ij}	A-56^{ef}		A-43
H			A-37^{j}	A-41^{hij}	A-44^{ghij}	A-57^{e}	A-52^{efg}	A-46
Mean			A-40	A-40	A-42	A-56	A-52	
			Marbling score[bc]					
C	Tr-12^{j}							
S		PD-80^{j}						
L			PD-82^{j}	Tr-15^{j}	Tr-42^{ij}			Tr-13^{m}
M			Tr-29^{ij}	Sl-01^{ghi}	Sl-26^{fgh}	Sm-05^{ef}		Sl-15^{l}
H			Tr-58^{hij}	Sl-42^{fg}	Sl-95^{ef}	Sm-02^{ef}	Sm-59^{e}	Sl-71^{k}
Mean			Tr-23^{n}	Tr-86^{m}	Sl-21^{l}	Sm-04^{k}	Sm-59^{k}	
			USDA quality grade[bd]					
C	St-56^{j}							
S		St-40^{j}						
L			St-46^{j}	St-58^{j}	St-77^{ij}			St-60^{m}
M			St-66^{ij}	G-14^{hi}	G-31^{gh}	G-87^{ef}		G-24^{l}
H			St-80^{ij}	G-48^{fgh}	G-77^{efg}	G-87^{ef}	C-08^{e}	G-60^{k}
Mean			St-65^{m}	G-06^{l}	G-28^{l}	G-87^{k}	C-08^{k}	

[a]C = control; S = submaintenance; L = low, M = medium, H = high ration energy density.

[b]0 to 33 = low; 34 to 66 = average; 67 to 100 = high.

[c]PD = practically devoid; Tr = traces; Sl = slight; and Sm = small amounts of marbling.

[d]St = standard; G = good; C = choice; inconsistencies between quality grade and marbling score are due to averaging.

[e,f,g,h,i,j]Treatment combination means within a factor without a common superscript letter are different ($P < .05$).

[k,l,m,n]Time on feed means within a row with a different superscript letter are different ($P < .05$); ration energy density means in a column within a factor with a different superscript letter are different ($P < .05$).

for all carcass traits except for RED effects on average maturity (tables 3,4). In general, as RED or TOF increased, values for carcass traits increased.

Similar results for carcass traits have been shown by other researchers for increasing RED (Ferrell et al., 1978; Foster and Miller, 1933; Guenther et al., 1962, 1965; Prior et al., 1977; Smith et al., 1977; Waters, 1908) and for increasing TOF (Dinius and Cross, 1978; Leander et al., 1978; Moody et al., 1970; Shinn et al., 1963).

Preston (1971) felt that nutritional effects on carcass composition were strongly influenced by differences in carcass weight. Analysis of covariance with hot carcass weight as the covariant was not applicable to this experiment because weight changes were automatically affected by treatment. However, hot carcass weight for L-119, M-91 and H-56 groups were similar. In these groups rib eye area, adjusted fat thickness, average maturity, marbling and quality grade were also similar. Only kidney, pelvic and heart fat and yield grade number were different. Guenther et al. (1965) and Prior et al. (1978) reported similar composition for carcasses of similar weights for cattle fed different RED.

Taste panel traits. Muscle fiber tenderness, overall tenderness, juiciness and flavor intensity scores (table 5) were not influenced by treatment combination ($P > .05$). Others have reported no difference for either TOF effects on palatability (Dinius and Cross, 1978; Graham *et al.*, 1959; Matthews and Bennett, 1962; Moody *et al.*, 1970) or for RED effects on palatability (Callow, 1961; Cole *et al.*, 1966; Davies, 1977; Henrickson *et al.*, 1965; Matthews and Bennett, 1962; Paul, 1962; Wanderstock and Miller, 1948; and Wellington *et al.*, 1954).

Detectable connective tissue scores were affected by treatment combination ($P < .05$). Steaks from the S group had the most detectable connective tissue, but the amount was similar to those of steaks from C, L-56 and H-147 groups. Decreases in connective tissue amount were not detectable in steaks from cattle fed 91 or more days on L rations or 56 or more days on M or H rations. Batterman *et al.* (1950) reported a decrease in total collagen of aged Holstein cows fed for 67 and 74 days. Smith *et al.* (1977) noted reduced taste panel evaluations (tenderness, flavor, acceptability) of steaks from steers off grass compared with those of steers fed a 20 or 60% roughage ration. However, the differences were small and disappeared with 49 days of feeding on a 20 or 60% forage ration. Steaks from the 178 day slaughter group had higher scores ($P < .10$) than those of the 56, 91, 119 or 147 days groups for muscle fiber tenderness,

TABLE 5. TASTE PANEL MEANS FOR LONGISSIMUS STEAKS FROM CATTLE FED DIFFERENT RATION ENERGY DENSITIES AND TIME ON FEED TREATMENTS

	Time on feed, days							
Ration[a]	0	28	56	91	119	147	178	Mean
				Muscle fiber tenderness[b]				
C	6.8							
S		6.8						
L			6.8	6.8	6.8			6.8
M			6.8	6.8	6.8	6.7		6.8
H			7.0	6.7	6.8	6.8	7.2	6.9
Mean			6.9^{g}	6.8^{g}	6.8^{g}	6.7^{g}	7.2^{f}	
				Detectable connective tissue[b]				
C	6.8^{de}							
S		6.5^{e}						
L			6.7^{de}	7.1^{cd}	7.0^{cd}			7.0
M			7.0^{cd}	7.3^{c}	7.1^{cd}	7.1^{cd}		7.1
H			7.3^{c}	7.0^{cd}	7.0^{cd}	6.8^{cde}	7.1^{cd}	7.0
Mean			7.0	7.1	7.0	7.0	7.1	
				Overall tenderness[b]				
C	6.7							
S		6.6						
L			6.6	6.8	6.8			6.7
M			6.8	6.9	6.7	6.8		6.8
H			7.0	6.7	6.8	6.6	7.1	6.8
Mean			6.8^{g}	6.8^{g}	6.8^{g}	6.7^{g}	7.1^{f}	
				Juiciness[b]				
C	6.4							
S		6.4						
L			6.0	5.9	6.0			6.0
M			5.8	5.9	6.3	5.8		6.0
H			6.0	6.0	5.8	6.3	6.4	6.1
Mean			5.9^{g}	5.9^{g}	6.0^{g}	6.0^{g}	6.4^{h}	
				Flavor intensity[b]				
C	6.5							
S		6.8						
L			6.2	6.3	6.7			6.4
M			6.3	6.2	6.5	6.4		6.4
H			6.6	6.3	6.4	6.4	6.6	6.5
Mean			6.4	6.3	6.5	6.4	6.6	

[a] C = control; S = submaintenance; L = low, M = medium, H = high ration energy density.

[b] Scores based on an eight point scale for each factor (1 = abundant connective tissue, extremely tough, dry or bland flavor; 8 = no connective tissue, extremely tender, juicy or intense flavor).

[c,d,e] Treatment combination means within a trait without a common superscript letter are different ($P < .05$).

[f,g] Time on feed means within a row with a different superscript letter are different ($P < .10$).

overall tenderness and juiciness scores, but this difference may not be of practical importance. Harrison et al. (1978), Kropf et al. (1975) Leander et al. (1978) and Shinn et al. (1976) reported increasing tenderness with increased TOF. Also increases in tenderness due to TOF appear to occur early in the feeding period (Smith et al., 1977; Zinn et al., 1970). However, Moody et al. (1970) and Matthews and Bennett (1962) noted no change in palatability with increasing TOF.

Objective textural traits. Values of Warner-Bratzler peak force and peak force minus initial yield force (table 6) were affected by treatment combination ($P < .05$); however, differences were small and no consistant pattern for these variables occured for RED and TOF treatment combinations. No differences were detected for treatment combination effects on adhesion and Warner-Bratzler initial yield force measurements ($P > .05$). Moody et al. (1970), Dinius and Cross (1978), and Matthews and Bennett (1962) reported no differences in Warner-Bratzler shear values for cattle fed increasing lengths of time on feed. Epley et al. (1968) noted Warner-Bratzler shear values of steaks from cattle fed 251 days were higher than those at 139 and 167 days on feed. Zinn et al. (1970) reported shear values decreased early in the feeding period and increased later in the feeding period.

Cohesiveness and chewiness textural measurements were highest for the C and S groups and tended to be lowest for the H-178 group ($P < .05$), with no improvement between 56 and 178 days on feed. Bouton and Harris (1972) stated that cohesiveness and chewiness measurements are related to connective tissue. Thus, our cohesiveness and chewiness measurement data agree with the greater amounts of connective tissue detected by the taste panel in the S and C groups.

TABLE 6. LONGISSIMUS WARNER-BRATZLER, ADHESION AND COMPRESSION MEANS FOR RATION ENERGY DENSITY AND TIME ON FEED TREATMENTS

	Time on feed, days							
Ration[a]	0	28	56	91	119	147	178	Mean
			Warner-Bratzler peak force, kg					
C	1.98^{cde}							
S		2.16^{bcde}						
L			2.02^{cde}	2.01^{cde}	2.15^{bcde}			2.06
M			1.96^{cde}	2.55^{b}	1.95^{cde}	2.14^{bcde}		2.15
H			1.76^{de}	2.32^{bc}	2.26^{bcd}	2.35^{bc}	1.72^{e}	2.08
Mean			1.91^{g}	2.29^{f}	2.12^{f}	2.24^{f}	1.72^{g}	
			Warner-Bratzler initial yield force, kg					
C	1.53							
S		1.55						
L			1.71	1.70	1.78			1.73
M			1.69	1.97	1.50	1.80		1.74
H			1.51	1.90	1.94	2.02	1.41	1.75
Mean			1.64^{fg}	1.86^{fg}	1.74^{fg}	1.91^{f}	1.41^{g}	
			Warner-Bratzler peak force minus initial yield force, kg					
C	.45^{bc}							
S		.60^{b}						
L			.31^{c}	.31^{c}	.37^{c}			.32
M			.27^{c}	.58^{b}	.45^{bc}	.35^{c}		.41
H			.26^{c}	.42^{bc}	.32^{c}	.34^{c}	.31^{c}	.33
Mean			.28	.44	.38	.34	.31	
			Adhesion					
C	2.71							
S		3.26						
L			3.96	4.44	4.53			4.31^{f}
M			3.66	2.26	2.94	3.40		3.07^{g}
H			2.02	4.44	3.83	3.08	2.60	3.20^{g}
Mean			3.22	3.72	3.77	3.24	2.60	
			Cohesiveness					
C	.45^{b}							
S		.41^{bc}						
H			.40^{bcd}	---	.36^{cd}	---	.35^{d}	.37
			Chewiness					
C	.91^{bc}							
S		.99^{b}						
H			.82^{cd}	---	.88^{bcd}	---	.73^{d}	.81

[a] C = control; S = submaintenance; L = low, M = medium, H = high ration energy density.

[b,c,d,e] Treatment combination means within a factor without a common superscript letter are different (P < .05).

[f,g] Time on feed means within a row with a different superscript letter are different (P < .05); ration energy density means in a column within a trait with a different superscript letter are different (P < .05).

Warner-Bratzler peak force and initial yield force were affected by TOF ($P < .05$). Warner-Bratzler peak force values were lower for 56 and 178 days as compared with 91, 119 and 147 days. Warner-Bratzler initial yield force values were lower at 178 than at 147 days, but values for 56, 91 and 119 days were similar to both the 178 and 147 day groups. However, all Warner-Bratzler shear force values were relatively low and differences, although significant, were small.

Taste panel and objective textural measurements indicate that the greatest differences in palatability occured in the C and S groups and was primarily attributed to connective tissue characteristics.

Sarcomere length. Sarcomere length (table 7) was influenced by treatment combination ($P < .05$). Steaks from cattle fed the S ration had the shortest *longissimus* sarcomere lengths. Control group sarcomere lengths were shorter than all L, M or H ration groups except M-56. With 56 or more days on feed all sarcomere lengths were longer than 1.85 um. Bouton *et al.* (1973) stated that sarcomere lengths greater than 1.8 um did not correlate well with tenderness differences in lamb.

Sarcomere lengths were not affected by TOF ($P > .05$). Leander *et al.* (1978) also reported no differences in *longissimus* sarcomere lengths for cattle fed 0, 56 or 112 days. However, sarcomere lengths of steaks from steers fed the H ration were longer than those from steers fed either the L or M ration.

TABLE 7. LONGISSIMUS SARCOMERE LENGTHS FOR RATION ENERGY DENSITY AND TIME ON FEED TREATMENTS

Ration[a]	Time on feed, days							
	0	28	56	91	119	147	178	Mean
			Sarcomere length, um					
C	1.84^{g}							
S		1.78^{h}						
L			1.96^{de}	1.92^{ef}	2.00^{bcde}			1.96^{j}
M			1.87^{fg}	1.96^{de}	2.03^{bcd}	2.01^{bcd}		1.97^{j}
H			1.97^{cde}	2.04^{bcd}	2.06^{b}	2.05^{bc}	2.02^{bcd}	2.03^{i}
Mean			1.93	1.97	2.03	2.03	2.02	

[a]C = control; S = submaintenance; L = low, M = medium, H = high ration energy density.

[b,c,d,e,f,g,h]Treatment combination means within a factor without a common superscript letter are different ($P < .05$).

[i,j]Ration energy density means within a column with a different superscript letter are different ($P < .05$).

Carcasses in the H group were heavier and fatter than those in the L or M groups and may have chilled slower resulting in less sarcomere shortening. Meyer _et al_. (1978) reported faster chilling rates for defatted loins of beef carcasses compared with loins with fat cover. Smith _et al_. (1976) stated that heavier lamb carcasses with greater fat thickness had longer _longissimus_ sarcomeres than lighter carcasses with less fat cover.

Conclusions

Ration energy density and TOF had minimal affects on taste panel traits of muscle fiber tenderness, overall tenderness, juiciness and flavor intensity, or objective textural measurements of adhesion and Warner-Bratzler peak force and peak force minus initial yield force. Connective tissue amounts as determined by taste panel and compression measurements indicate more connective tissue in steaks from the C and S groups. However, differences were small and disappeared with as little as 56 days of feeding. Sarcomere lengths were influenced by RED and TOF combinations but the differences were not reflected in taste panel tenderness scores or objective textural measurements.

If TOF plays a role in palatability of beef, its affect may have occured before the start of the trial during the early growing period or during the 21 day ration adjustment period.

Even though differences in palatability were small and not strongly affected by TOF or RED, meat from steers fed a low energy density ration for 56 days is not necessarily equivalent to that from steers fed 178 days, as ultimate consumer acceptance also depends on factors such as display color stability, muscle size, and USDA quality grade.

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APPENDICES

APPENDIX A
PALATABILITY SCORE SHEET

Panelist's Name: ____________________ Date: ____________

Sample	Muscle Fiber Tenderness	Amount of Connective Tissue	Overall Tenderness	Juiciness	Flavor Intensity
1					
2					
3					
4					
5					
6					
7					

Muscle Fiber Tenderness	Amount of Connective Tissue	Overall Tenderness	Juiciness	Flavor Intensity
8. Extremely Tender	8. None	8. Extremely Tender	8. Extremely Juicy	8. Extremely Intense
7. Very Tender	7. Practically None	7. Very Tender	7. Very Juicy	7. Very Intense
6. Moderately Tender	6. Traces	6. Moderately Tender	6. Moderately Juicy	6. Moderately Intense
5. Slightly Tender	5. Slight	5. Slightly Tender	5. Slightly Juicy	5. Slightly Intense
4. Slightly Tough	4. Moderate	4. Slightly Tough	4. Slightly Dry	4. Slightly Bland
3. Moderately Tough	3. Slightly Abundant	3. Moderately Tough	3. Moderately Dry	3. Moderately Bland
2. Very Tough	2. Moderately Abundant	2. Very Tough	2. Very Dry	2. Very Bland
1. Extremely Tough	1. Abundant	1. Extremely Tough	1. Extremely Dry	1. Extremely Bland

APPENDIX B

CALCULATION OF OBJECTIVE TEXTURAL MEASUREMENTS

Instron Warner-Bratzler (figure 1A).

a. Peak force: heigth at PF.

b. Initial yield force: Heigth at IYF.

c. Peak force minus initial yield force: the distance of C-A.

Instron compression (figure 1B).

a. Cohesiveness: area under the second curve (W2) divided by the area under the first curve (W1).

b. Chewiness: PF1 multiplied by the cohesiveness value.

Instron adhesion (figure 1C).

a. Adhesion: heigth at AH.

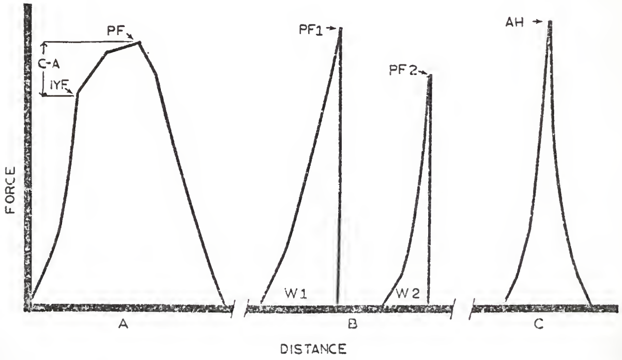

FIGURE 1. TYPICAL INSTRON FORCE-DEFORMATION CURVES FOR: A. WARNER-BRATZLER; B. COMPRESSION; C. ADHESION

APPENDIX C

SLAUGHTER WEIGHT, DRESSING PERCENTAGE, ACTUAL FAT THICKNESS, BONE MATURITY AND LEAN MATURITY MEANS FOR RATION ENERGY DENSITY AND TIME ON FEED TREATMENTS

Ration-time treatments[a]	Slaughter weight, kg	Dressing[b] %	Actual fat th.,cm	Bone maturity[c]	Lean maturity[c]
C	276.0^{j}	56.8^{g}	$.28^{ghi}$	$A\text{-}20^{j}$	$A\text{-}52^{def}$
S	285.8^{j}	54.5^{h}	$.11^{i}$	$A\text{-}31^{fghi}$	$A\text{-}69^{d}$
L-56	323.7^{i}	54.3^{h}	$.16^{hi}$	$A\text{-}30^{ghi}$	$A\text{-}59^{de}$
M-56	344.3^{hi}	54.6^{h}	$.27^{ghi}$	$A\text{-}25^{ij}$	$A\text{-}55^{def}$
H-56	345.8^{hi}	56.7^{g}	$.41^{g}$	$A\text{-}28^{hi}$	$A\text{-}44^{ef}$
L-91	333.1^{i}	56.9^{g}	$.30^{ghi}$	$A\text{-}35^{fgh}$	$A\text{-}59^{de}$
M-91	373.2^{g}	57.0^{g}	$.41^{g}$	$A\text{-}30^{ghi}$	$A\text{-}49^{ef}$
H-91	372.7^{g}	59.8^{f}	$.73^{f}$	$A\text{-}36^{fg}$	$A\text{-}47^{ef}$
L-119	335.3^{gh}	57.4^{g}	$.35^{hi}$	$A\text{-}39^{ef}$	$A\text{-}49^{ef}$
M-119	404.2^{f}	59.7^{f}	$.67^{f}$	$A\text{-}34^{fgh}$	$A\text{-}40^{f}$
H-119	411.4^{ef}	61.4^{ef}	$.76^{f}$	$A\text{-}44^{e}$	$A\text{-}45^{ef}$
M-147	434.1^{e}	62.1^{e}	$.71^{f}$	$A\text{-}51^{d}$	$A\text{-}60^{de}$
H-147	465.4^{d}	62.9^{d}	$.98^{e}$	$A\text{-}54^{d}$	$A\text{-}60^{de}$
H-178	465.0^{d}	63.8^{d}	1.24^{d}	$A\text{-}54^{d}$	$A\text{-}50^{ef}$

[a] C = control; S = submaintenance; L = low, M = medium, H = high ration energy density.

[b] Calculated as hot carcass weight divided by slaughter weight times 100.

[c] 0 to 33 = low; 34 to 66 = average; 67 to 100 = high.

[d,e,f,g,h,i,j] Means within a column without a common superscript letter are different ($P < .05$).

APPENDIX D

FAT COLOR, LEAN TEXTURE AND FIRMNESS, AND MARBLING TEXTURE AND DISTRIBUTION MEANS FOR RATION ENERGY DENSITY AND TIME ON FEED TREATMENTS

Ration-time treatments[a]	Fat color[b]	Lean texture[c]	Lean firmness[c]	Marbling texture[c]	Marbling distribution[c]
C	1.8[fg]	4.8[efg]	3.0[h]	4.1[fg]	4.3[def]
S	2.1[de]	4.6[efg]	5.6[def]	3.9[g]	3.4[ef]
L-56	2.4[d]	3.1[h]	4.4[fg]	3.9[g]	2.9[f]
M-56	2.1[de]	4.1[fgh]	5.0[efg]	4.1[fg]	3.8[def]
H-56	2.0[ef]	4.5[efg]	5.9[de]	4.8[defg]	4.1[def]
L-91	1.9[ef]	3.5[gh]	4.0[gh]	3.8[g]	2.8[f]
M-91	1.5[ghi]	4.2[fgh]	5.8[de]	4.6[defg]	4.1[def]
H-91	1.6[gh]	4.6[efg]	6.8[d]	4.4[efg]	4.5[de]
L-119	1.3[hij]	5.0[def]	5.5[ef]	4.3[efg]	3.8[def]
M-119	1.2[ij]	5.8[de]	5.9[de]	5.4[de]	5.0[d]
H-119	1.1[j]	5.8[de]	6.4[de]	4.5[efg]	4.8[de]
M-147	1.3[hij]	5.9[de]	5.9[de]	5.1[def]	5.0[d]
H-147	1.1[j]	5.9[de]	6.6[d]	4.6[defg]	4.5[de]
H-178	1.0[j]	6.6[d]	6.6[d]	5.6[d]	5.1[d]

[a]C = control; S = submaintenance; L = low, M = medium, H = high ration energy density.

[b]Five point scale (1 = white, 5 = extremely yellow).

[c]Eight point scale (1 = very coarse, uneven or soft; 8 = very fine, uniform or firm).

[d,e,f,g,h,i,j]Means within a column without a common superscript letter are different ($P < .05$).

RATION ENERGY DENSITY AND TIME ON
FEED EFFECTS ON BEEF LONGISSIMUS PALATABILITY

by

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This study was designed to evaluate time on feed and ration energy density effects on palatability of beef longissimus steaks.

One hundred twelve Angus yearling steers of similar background were randomly allotted to each of 14 nutritional treatments (eight per treatment) after a 21 day ration adjustment period. Treatment groups were: controls (C), slaughtered after the adjustment period; submaintenance (S), fed prairie hay to lose .5 kg/day for 28 days before slaughter; and the twelve remaining groups were fed either a low (L), medium (M) or high (H) energy density ration (.771, .992 and 1.28 Mcal NEp/kg, respectively)and slaughtered after 56, 91, 119, 147 (M and H only), or 175 (H only) days on feed. Carcass data were collected after chilling 24 hours postmortem.

Longissimus samples from the rib were collected seven days postmortem. A trained taste panel evaluated samples for muscle fiber tenderness, detectable connective tissue, overall tenderness, juiciness and flavor intensity. Objective textural assessments were obtained using an Instron equipped for Warner-Bratzler, adhesion and compression measurements. Sarcomere lengths were measured using phase contrast microscopy.

Average daily gains for the S, L, M and H rations were -.21, .81, 1.18 and 1.35 kg/day, respectively and for 56, 91, 119, 147 and 178 days on feed were 1.27, 1.07, 1.06, 1.26 and 1.21 kg/day, respectively. Yield

grade number ranged from 1.1 for L-56 to 3.4 for H-178 and quality grade ranged from standard 40% for S to choice 7% for H-178.

Taste panel muscle fiber tenderness, overall tenderness, juiciness and flavor intensity scores were not influenced by treatment ($P > .05$). Treatment significantly affected detectable connective tissue ($P < .05$). S group had the most detectable connective tissue; but, the amount was statistically similar to those for C, L-56, and H-147 groups. Decreases in connective tissue amount were not detectable in steaks from cattle fed 91 or more days on L rations or 56 or more days on M or H rations.

Time on feed tended to increase muscle fiber tenderness, overall tenderness and juiciness scores. Steaks from the 178 day slaughter group had more desirable scores ($P < .10$) than the 56, 91, 119 or 147 days groups for all three traits.

Values for peak force and peak force minus initial yield force were affected by treatment ($P < .05$); however, no consistnat pattern for these variables occurred for ration and time treatments. Cohesiveness and chewiness textural measurements were highest for the C and S groups and lowest for the H-178 group ($P < .05$). No differences were detected for treatments for adhesion and initial yield force measurements ($P > .05$).

Sarcomere lengths were significantly affected by treatment. *Longissimus* sarcomere lengths of the S group (1.73 um) were the shortest of all groups ($P < .05$). C group sarcomere lengths were shorter than those for L, M and H ration groups except M-56. Sarcomere lengths of H ration groups were longer than those of L or M ration groups.